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Determining the skilful forecast range for probabilistic prediction of system-wide wind power generation

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Introduction

State-of-the-art wind power forecasts beyond a few hours ahead rely on global numerical weather prediction models to forecast the future large-scale atmospheric state. Often they provide initial and boundary conditions for nested high resolution simulations. Here, upper and lower bounds on forecast range are identified within which global ensemble forecasts provide skilful information for system-wide wind power applications. Both bounds depend on the global forecast system.

Evaluation using observed wind power generation

Estimates of wind speed from meteorological analyses or forecasts are converted to wind power generation aggregated across Great Britain (GB) following the methodology of Cannon et al. (2015). The power system of GB is used as an example because measured power system data is available from National Grid to evaluate the forecasts. The steps are:

i) interpolate wind speed from global model grid to wind farm locations.

ii) fit a logarithmic wind profile to the lowest model level data and infer wind speed at a representative turbine hub height.

iii) transform wind speed to power using a typical wind farm power curve.

iv) aggregate over all wind farms metered in the national transmission network (Fig 1), i.e., excluding small-scale farms embedded in local distribution networks.

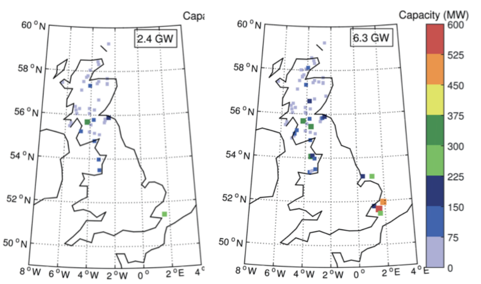


Fig. 1: Wind farm capacity (excluding embedded). Left: Sept 2009, Right Dec 2012.

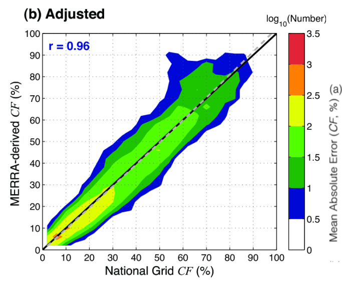


***Fig. 2:** Estimated GB-aggregated capacity factor (for 2012, see Cannon et al 2015). Re-analyses give excellent estimates on regional scales (GB is ~800x400km).*

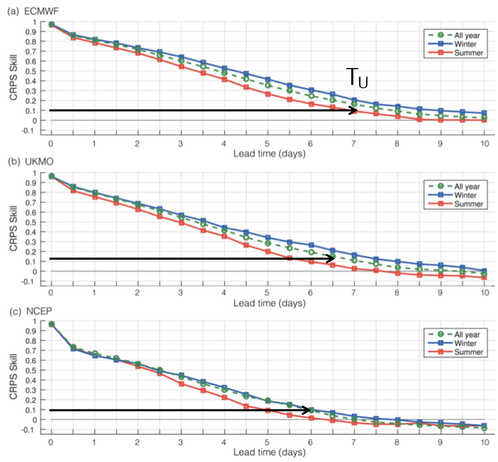
Upper bound on forecast range

Ensemble forecasts from ECMWF, Met Office and NCEP are used to calculate an upper time bound or *limit of predictive skill* for forecasts of GB-aggregated wind power generation. The forecasts are obtained from the TIGGE data portal (see Swinbank *et al.*, 2016) on a 0.5°x0.5° grid.

Differences between the ensemble forecast of GB capacity factor (c) and the value derived from analysis are used to calculate the CRPS (Continuous Ranked Probability Score). This is compared with the score for a simple forecast based on the climatological statistics of c to construct the skill score:

$$CRPSS = 1 - \frac{CRPS_{forecast}}{CRPS_{climatology}}$$

***Fig. 3:** The upper bound, T_U, on useful forecast range is defined here when the CRPSS first drops to 0.1 (barely any more skill than climatology).*

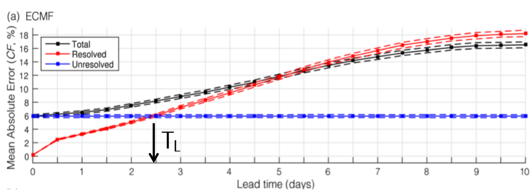


Lower bound on forecast range

The absolute error in forecasts of wind capacity is decomposed into:

- **"resolved uncertainty"** - the deviation of the ensemble mean forecast from the corresponding analysis, $\mathrm{MAE_R} = \frac{1}{N}\sum_i |f_i(l) - a_i|$
- **"unresolved uncertainty"** - the error in analysis estimate compared to the observed capacity, $\mathrm{MAE_U} = \frac{1}{N}\sum_i |a_i - o_i|$

***Fig. 4:** Lower bound on forecast range is defined as lowest lead time, T_L, when $\mathrm{MAE_R} > \mathrm{MAE_U}$*



Probability forecasts for ramping

At lead times of days to weeks, transmission system operators are concerned with the likelihood of extreme events such as ramps in wind power generation. Ensemble forecasts provide users with the capability of forecasting the probability of these events.

***Fig. 5:** A ramp is said to have occurred if max-min capacity factor within a future time window is larger than a threshold. The lead time is identified with the centre of the window.*

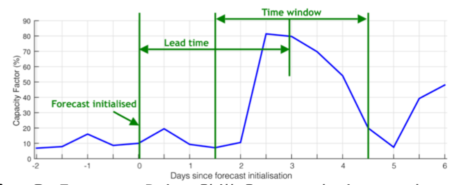
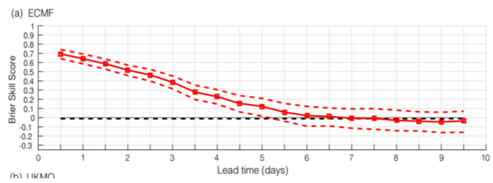


***Fig. 6:** Forecast Brier Skill Score relative to the re-analysis climatological frequency (for same calendar date using a 6-day moving window).*



Conclusions

Upper and lower bounds on forecast range are identified within which global ensemble forecasts provide skilful information for system-wide wind power applications

$$T_L < l < T_U$$

T_U = limit of predictive skill in probability forecasts related to chaos and ensemble spread

T_L = time taken for spread of ensemble (resolved uncertainty) to exceed forecast error in wind power associated with other factors (unresolved uncertainty).

"Unresolved" factors include representation of terrain & local wind phenomena, wind to power transform & generation onto power grid.

Downscaling from global is expected to be effective for lead times, $l < T_L$ (1.4-2.4 days)

T_U is shorter for wind ramping than capacity itself, and depends strongly on global forecast ensemble chosen.

References

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